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EFFECTS OF THE FLIGHT SPEED OF PASSENGER AIRCRAFT ON FLIGHT NOISE AND OF THE NOISE DURATION ON SUBJECTIVE ESTIMATES OF NOISE INTENSITY

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ABSTRACT. A discussion is presented of the aircraft noise problem, based on noise observations of Soviet domestic passenger aircraft and the Caravelle aircraft. Graphs of noise levels versus aircraft speed are plotted, and an ampirical formula is presented which takes noise duration into account. The results for noise levels as a function of flight speed are believed to be applicable to all jet-powered passenger aircraft, and in the first approximation to turboprops as well, even though they are largely based on observations in the TU-104 and TU-124 aircraft.

The flight noise created during takeoffs and landings of aircraft in the areas around airports is limited at the present time to perceived noise levels of 110-112 PN db in the daytime and 102 PN db at night. /562[1]

The necessity of observing these required flight noise levels at relatively short distances from the airport (usually at a distance of 4-6 km from the beginning of the aircraft run, the point where housing construction generally begins around airports) makes it necessary to use various measures designed to reduce the noise [1], including particularly an increase in the inclination of the climbing flight path by special piloting techniques. Climbing more rapidly, the aircraft flies over populated points at a higher altitude and the total level of flight noise in decibels is decreased, under otherwise equivalent conditions, by approximately $\Delta SL_H = 20 \log H/h$, where h and H are the altitudes above the populated points with the standard climbing rate performed with increased speed and at the steeper climbing rate performed at decreased constant speed. However, decreasing the flight speed causes an increase in flight noise and may quite essentially decrease the positive effects resulting from increasing flight altitude. Therefore, the estimate presented below of the influence of flight speed on flight noise is of essential practical significance.

Figure 1 shows data on the influence of flight speed on the difference between the maximum summary stationary noise level SL_0 and the summary level of of flight noise SL_V at the same distance from the aircraft produced for domestic passenger aircraft and taken for the DC-8 and Caravelle aircraft from the literature [2]. The small symbols on the graph show the results of individual

[1] Numbers in the margin indicate pagination in the foreign text.

measurements: the black circles and squares represent results for the TU-104 and TU-124 aircraft for flights at maximum engine power, while the white circles and squares show the results for flights performed using nominal engine operation. The larger symbols show the mean results of large groups of measurements; the solid circles and squares show results for TU-104 and TU-124 aircraft flying at maximum engine power, the light symbols -- at nominal power, the crosshatched symbols represent flights at maximum power and 0.8 -- at nominal power. The triangles with indices 1 through 5 show the mean results of large groups of measurements for flights at the maximum or nominal engine power level for the TU-114, IL-18, AN-10, AN-24 and IL-14 aircraft respectively; the triangle marked 6 shows data from the DC-8 flying at maximum engine power, and the triangle marked 7 represents the Caravelle aircraft flying at nominal engine power. /563
Measurements were performed using various flight altitudes. The curve on Figure 1 is the geometric locus of the mean values of all experimental data at the given flight speed. It was constructed in consideration of the fact that the small symbols correspond to individual measurements, the larger symbols to groups of various numbers of measurements.

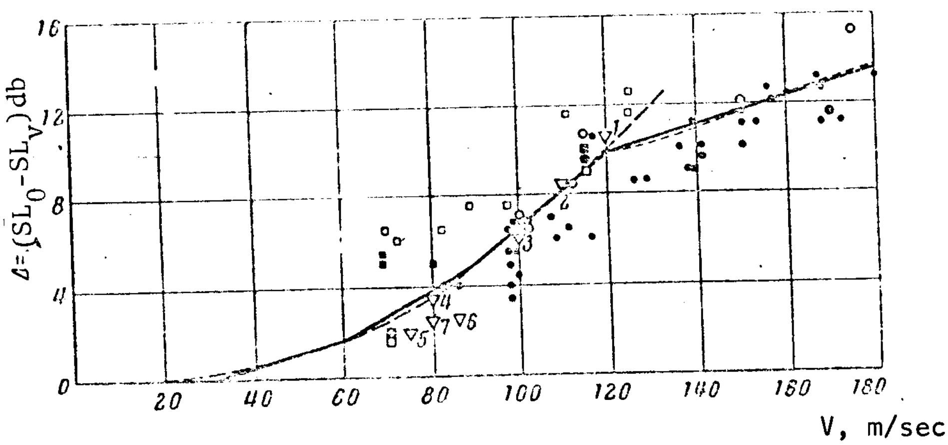

Figure 1

Although the mechanism by which the flight speed influences the noise of a jet aircraft and a turboprop aircraft or piston aircraft is not the same, nevertheless, in the final analysis, according to widespread experimental data, this has practically no influence on the change in the noise level as a function of flight speed; in this same way, the change in the noise level resulting from a change in flight speed does not depend on the flight altitude or on the operating mode of the motor. For example, if such different aircraft as the IL-14, TU-124 and Caravelle fly at approximately the same speed (see Figure 1), their maximum stationary noise level is decreased by practically the same degree.

The amount of change in the noise level as a function of changes in flight speed can be determined graphically from Figure 1, or using empirical formulas. In the range of aircraft flight speeds from 0 to 120 m/sec, the mean value of quantity $\Delta = SL_0 - SL_V$ can be calculated using the following empirical formula: $\Delta = 6.3 \div 10^{-5}\ V^{2.5}$ db (the dotted line on Figure 1), and at higher speeds, from from the formula: $\Delta = 0.234 \div V^{0.78}$ db (dotted line on right side of Figure 1). Calculation of changes in Δ can also be performed using the simpler empirical formula corresponding to the solid, broken curve on Figure 1: $\Delta = a_1V_1b_1 - - a_2V_2 - b_2$, where Δ is the increase in summary level or perceived noise level as a function of changing speed, V_1, m/sec is the initial flight speed, V_2, m/sec, is the new flight speed, the influence of which is to be evaluated. Coefficients a and b are determined by the table:

V, m/sec	a	b
30-60	+0.06	-1.8
60-90	+0.1	-4.2
90-120	+0.17	-10.5
120-180	+0.06	+2.7

This dependence makes it possible for us to determine by calculation the flight noise level for any aircraft if we know, either by direct measurement or by calculation according to the values of the parameters of the engines used, the maximum noise level SL_0 under stationary conditions at range R from the aircraft, where $60 \leqslant R \leqslant 100$ m. Determination of flight noises is performed /564 using the graph shown on Figure 2. On this graph, for any arbitrarily selected level of sound pressure (abscissa) the quadratic dependence of the attenuation in sound with increasing distance resulting from the expansion of the spherical sound wave front is shown by the thin line, then, considering the experimentally determined additional sound attenuation, the actual attenuation of stationary noise with increasing distance is shown (curve for V = 0).

In order to determine flight noise, the quadratic dependence of attenuation of SL_0 (thin line) is shifted to the left while retaining the same inclination by the quantity Δ taken from Figure 1; furthermore, for altitudes exceeding 300 m, the experimental correction which we have produced which indicates the additional attenuation of the summary level of flight noise as a result of absorption in the air must be added in. Thus, we produce the dependence of the change in flight noise on range for Δ equal to 4, 6, 8, 10 and 12 db, shown on Figure 2 by the solid lines. For aircraft with jet motors, which have a distinctive pattern of sound radiation directionality, we must introduce yet another correction to consider the fact that at the moment when the maximum noise is excited at a given point on the ground, the distance to the aircraft from the point is greater than the flight altitude above the point. The dotted lines on Figure 2 include the consideration of this factor.

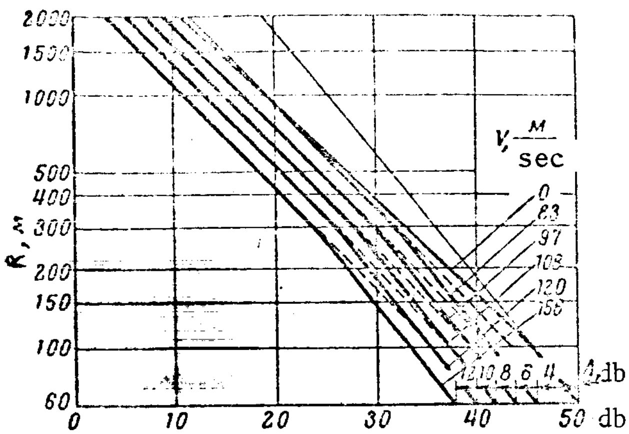

Figure 2

Using the graph of Figure 2, we can determine the flight noise created by any modern passenger aircraft flying at various altitudes H, velocities V and motor operating modes (as well as the maximum stationary noise at ranges up to 2000 m) if we know the maximum stationary noise SL_0 for the given operating mode of the engines at a range from the aircraft $60 \leqslant R \leqslant 100$ m.

Let us explain the practical utilization of the graphs of Figure 2 using a concrete example. Suppose we must determine the flight noise created by a TU-104 aircraft flying at various altitudes at maximum engine power and a flight speed of 115 m/sec, if we know that under stationary conditions at a range R = 60 m with maximum engine power SL_0 = 133 db.

At R = 60 m, the arbitrary sound pressure level, according to Figure 2, is 50 db. The difference d = 133 - 50 = 83 db. The flight speed of 115 m/sec corresponds to a difference Δ = 9 db (Figure 1) and, consequently, to a curve passing between the second and third curves from the left on Figure 2. Drawing this curve mentally, considering the fact that for a jet aircraft it should be equidistant with the dotted line curves at low altitudes, we find the arbitrary levels of sound pressure for flight altitudes H = 100, 200, 300, 400 and 500 meters of 38.5, 31, 27, 24 and 21.5 db respectively or, adding to these values d = 83 db, summary flight noise levels of 121.5, 114, 110, 107 and 104.5 db. The corresponding averaged experimental values at flight speeds of 115 m/sec are 119.5, 113, 110, 107 and 105 db. /565

The system of normalizing noise in PN db which has become widely used in recent times does not take into consideration the duration of the action of the noise during aircraft overflights. Nevertheless, this factor determines the irritant effect of noise on the population to a great extent [3].

The reduction in flight speed and the greater flight altitude over a populated point resulting from usage of the "low noise" takeoff method results in an essential increase in the duration of action of the noise. Doubling the time of application of a noise is equivalent to increasing its level by 3 db, if we assume that the summary noise energy to which the population is exposed is thus doubled. According to the results of work [4], doubling the time of exposure to a sound is perceived as an increase in its intensity by even more than 3 db (up to 4.5 db).

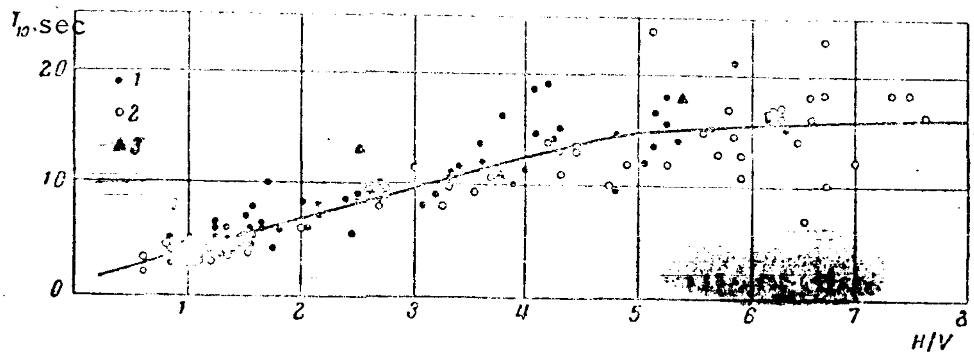

Figure 3

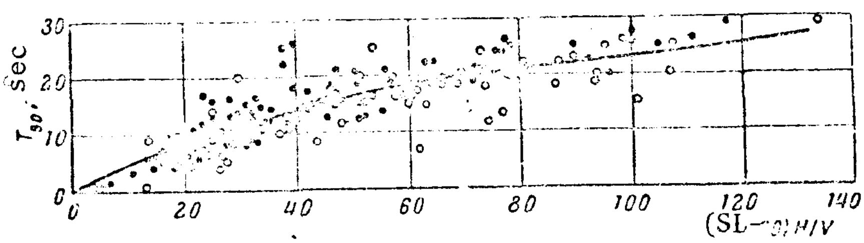

Figure 4

The measure of the duration of action of aircraft noise commonly accepted at the present time is the time during which its upper 10 db are heard [5]. Figure 3 shows the dependence of this quantity (T_{10}, sec) on the parameter of the ratio of height H,m to flight speed V,m/sec, produced as a result of experimental investigations performed during overflights of TU-104 (1), TU-124 (2) and Caravelle (3) aircraft at various altitudes in the 60-600 m range with various flight speeds, with the engines operating at takeoff, nominal, cruising and landing power levels.

The time during which the top 10 db are heard, in our opinion, does not fully characterize the degree of irritation during an aircraft overflight, since under otherwise equivalent conditions the irritating effect is determined by the maximum level of the flight noise. It seems to us that the same exposure duration to the upper 10 db with a maximum level of 120 db would be more /566
irritating to the population than with a maximum level of 100 or 90 db. Due to this, we suggest that the time of action of the noise be taken as the time during which its level exceeds 90 db (the characteristic background level in the zone around a modern airport with intensive air movement during the daytime) or 80 db for the takeoff-landing areas located, let us say, at the edge of the city. Figure 4 shows an experimental graph of the dependence of the exposure time of flight noise over a level of 90 db (T_{90},sec) on the parameter (SL - 90)H/V, where (SL - 90), db, is the amount by which the maximum summary level exceeds 90 db. Assuming that the increase in exposure time to the noise is equivalent to an increase in its perceived level of 3 db, we produce the

correction ΔPN db_T for increased exposure time to the noise, which in this case can be determined by the graph of Figure 5 (along the ordinate we see T_{90n}/T_{90m}, along the abscissa -- ΔPN db_T) and the experimental formula:

$$\frac{T_{90n}}{T_{90m}}=\frac{A_n+B_n(SL_n-90)H_n/V_n}{A_m+B_m(SL_m-90)H_m/V_m},$$

where T_{90n}, sec, is the time during which the noise level exceeds 90 db under conditions n, characterized by the quantities SL_n, db, H_n, m and V_n, m/sec; T_{90m} is the same under conditions m, $T_{90n} > T_{90m}$. Coefficients A and B are determined from the following table:

(SL - 90)H/V	A	B
0-30	0	0.4
30-70	6	0.2
70-130	11	0.125

If we assume that increasing the exposure time of the noise is equivalent to increasing its perceived level by 4.5 db [3, 4], the value of ΔPN db_T produced from the graph on Figure 5 should be increased by a factor of 1.5.

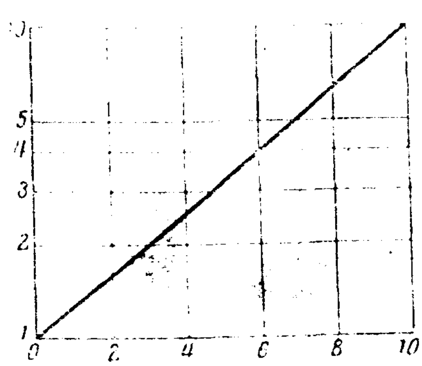

Figure 5

We must note that the formula and the graph for ΔPN db_T do take into consideration the influence of altitude H and flight speed V only on the duration of action of noise T_{90}, and, through its effect on the duration, consider also its effect on the perceived noise level; the influence which flight altitude and speed have on the summary flight noise level and consequently on the perceived noise level is not taken into consideration.

In spite of the fact that the experimental investigations used in this article are concerned primarily with the TU-104 and TU-124 aircraft, checks of the available experimental material indicate that these relationships are applicable for other types of jet-passenger aircraft as well, and in the first approximation are also applicable to turboprop powered aircraft.

REFERENCES

1. Aeroport de Paris - Le Bourget, Consignes Anti-noise, No. 03, 1963. Aeroport de Paris - Orly, Consignes Anti-noise, No. 03, 1963.
2. Ingerslev, F., and E. Smed, Acoustic Tests on Jet Aircraft, The Danish Academy of Technical Sciences, Copenhagen, 1961.
3. "Wilson Committee Report on Noise," Aircraft Engng., Vol. 35, No. 8, pp. 218-219, 1963.
4. Kryter, K. D. and K. S. Pearsons, "Some Effects of Spectral Content and Duration on Perceived Noise Level," J. Acoust. Soc. America, Vol. 35, pp. 866-886, 1963.
5. Boll, Beranek, Newman, Inc., Studies of Noise Characteristics of the Comet 4 Jet Airliner and of Large Conventional Propeller-Driven Airliners, 1958.

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